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WATERSHED MANAGEMENT PROBLEMS IN THE NORTHERN ROCKY MOUNTAIN REGION

BY

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COVER PHOTOGRAPH:

North Fork of Flathead River,
Flathead National Forest
Montana

(U.S. Forest Service photo)

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INTRODUCTION

Water that falls as snow and rain on mountain slopes of the Continental Divide is one of the most important natural resources in the drainage basins of the Columbia and Missouri Rivers. As this water moves down these two great river systems, considerable effort is directed toward regulating its flow to serve the numerous uses that depend upon it. Those who live in these basins have become aware, often painfully so, that the amount and condition of water flowing in these rivers exert tremendous influence upon personal, economic, social, and recreational affairs. Power plants have been erected to generate electricity for the demands of a rapidly increasing population and expanding economy. Large dams have been built to protect people and property against floods and to impound water for irrigation. Lakes formed by these impoundments have become scenes of intensified recreational developments for boating, fishing, and swimming.

Most of the interest displayed over water in the Columbia and Missouri River Basins is related to development of facilities to control it and put it to use after it enters larger tributaries and main streams. Unfortunately, there has been much less concern about controlling water where it first falls on the land in greatest abundance and where it is susceptible to management for control; namely, on upstream forest and range watersheds. Experience in many places has shown that a change in the disposition by the soil mantle of only a small portion of the water received may greatly affect the manner in which it is delivered as streamflow. The behavior of water and whether it is beneficial or harmful depends, in great measure, upon the condition and the uses of the lands from which it drains.

The Northern Region[1/] administered by the U.S. Forest Service occupies a strategic position with respect to the water resources of the entire Columbia and Missouri River Basins. Straddling the Continental Divide, this region lies almost entirely within the headwaters of these rivers. It contains extensive coniferous forests that are being harvested and converted

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1/ The term "Northern Region" refers specifically to the six counties in the northeastern corner of Washington, that part of Idaho north of the Salmon River, all of Montana, the northwestern corner of South Dakota, and the northwestern corner of Wyoming (most of Yellowstone National Park). Likewise, when the terms "Columbia Basin" and "Missouri Basin" are used, it is to be understood that they refer only to that portion of either basin that lies within the Northern Region unless otherwise specified.

from a decadent old-growth condition to vigorously growing young forests. It also contains large areas of range land where many livestock and big game animals graze. The method of managing these forests and ranges can have far-reaching effects upon the condition of the vegetation and soil, and, hence, upon the quality, amount, and rate of water delivered to creeks and rivers.

Since 1905, when the national forest system was created, methods of managing the timber and forage resources have been improved. Most of these improvements were developed mainly in the interest of better production of timber and forage. Few were directed specifically at betterment of watershed conditions although some have effected improvement incidentally. Management problems concerning the influence of various resource use activities on water and soil continue to arise. Some of these problems involve methods of maintaining effective control of water and soil movement under continued timber harvesting, grazing, and recreational uses. Others are concerned with restoring control over water and soil on watersheds where it has been lost through overuse, abuse, or some catastrophe such as wildfire. Still others involve the management of timber and forage resources to improve water-yielding characteristics of watersheds, especially the amount and quality of water and the time of year when it appears as streamflow.

Satisfactory solutions for most of these problems require watershed management research, a need long recognized but only recently implemented in this region. Accurate knowledge is needed of climatic elements; of interrelations between climate, vegetation, and soil; and of quantitative effects of vegetation and soil on amount, rate, time, and quality of streamflow. Management practices designed specifically to provide desired conditions of streamflow and control of soil must be developed and evaluated.

This report delineates the high priority problems of watershed management on forest and range lands of the upper Columbia and Missouri River drainages. To evaluate the relative importance of these problems it is necessary to understand their scope and the nature of the factors that influence them. This requires a thorough knowledge of: (1) pertinent facts about the existing water situation; (2) the nature of water problems in these two basins; and (3) the manner by which the physical features and resource uses of the region bear on these water problems. This report is not intended to be an exhaustive analysis of general watershed problems and research needs. Rather, it is a condensed summary of a more detailed watershed management research problem analysis recently developed for this area. It should engender interest in watershed management problems and should stimulate research efforts toward their solution.

THE WATER SITUATION

COLUMBIA RIVER BASIN

At its mouth the Columbia River discharges an average annual runoff of nearly 180 million acre feet from about 166 million acres. Of this amount about 41 million acre feet are produced on 35 million acres within the boundaries of the Northern Region (5).

The Columbia River Basin has great potentialities for development. About 4 million acres of land are already irrigated. Comprehensive basin development plans include irrigation of 3.8 million more acres and provision of supplemental water for about 1.5 million acres now irrigated (13).

Installed hydroelectric power capacity is about 5.9 million kilowatts. Potentially, the Columbia River is the greatest power-producing stream in America and one of the greatest in the world. Existing plans, if carried out, would create approximately 11.4 million kilowatts' installed capacity. Potential capacity is estimated at nearly 34 million kilowatts or 40 percent of the Nation's total estimated potential (11).

Existing storage capacity of irrigation, power, and flood control structures on the Columbia River is about 9.5 million acre feet. These structures plus those under construction, authorized, and recommended, would provide about 27 million acre feet of storage. Of this, about 19 million acre feet are considered necessary for control of major floods on the lower Columbia River. The potential developable storage capacity of the entire basin is estimated to be about 100 million acre feet (11).

The total investment to date for irrigation, power, and flood control developments in the entire Columbia Basin is approximately 2 billion dollars. Installation of authorized and recommended developments would bring this investment to about 7.6 billion dollars (12).

MISSOURI RIVER BASIN

At its confluence with the Mississippi River the Missouri River discharges an average of about 59 million acre feet annually from an area of 339 million acres. Of this amount, approximately 17 million acre feet originate on about 82 million acres of Northern Region land. Thus, the Missouri River discharges approximately one-third as much water from about twice as great an area as the Columbia does.

The chief potential of the Missouri River Basin lies in its development for irrigation agriculture. About 5 million acres of this basin are now irrigated. Proposed plans would provide irrigation for about 2.5 million additional acres plus provision of supplemental water for about 250,000 acres now irrigated. Irrigable land in the Missouri Basin, if fully developed, would total nearly 13 million acres (14).

Installed hydroelectric power capacity is only about 928,000 kilowatts, or one-sixth that of the Columbia Basin. Authorized and approved developments would increase this to 3.1 million kilowatts. The potential for development--nearly 6.6 million kilowatts--is still only about one-fifth that of the Columbia Basin (9).

Live storage capacity of existing reservoirs on the Missouri is more than 16 million acre feet. This storage plus that under construction will provide nearly 49 million acre feet of water (10).

The total investment to date for irrigation, power, and flood control facilities in the Missouri River Basin is about 1.9 billion dollars. Completion of projects under construction plus those authorized and recommended would raise this investment to nearly 8.5 billion dollars (8).

Thus, the total cost of water handling facilities in the two basins that depend heavily upon clean, usable water from the forest and range lands of the Northern Region is now about 3.9 billion dollars. Developments that would eventually increase this value to more than 15 billion dollars have already been proposed. Many more billions are already invested in agriculture and industry whose very existence depends upon water and power controlled and distributed by these facilities. Hence, the reliance placed upon water from this region is an integral part of the national, regional, and local economy.

WATER PROBLEMS OF THE COLUMBIA AND MISSOURI RIVER BASINS

Of primary and recurring concern to people living in the Columbia and Missouri River Basins are five important water problems:

1. How to control snowmelt floods, especially on main tributary streams.

2. How to prevent sediment from entering stream channels where it can be carried into power and irrigation reservoirs, water supply systems, and even onto irrigated farm lands.

3. How to increase water supplies for late summer irrigation where sufficient storage facilities cannot be developed.

4. How to improve winter streamflow to insure power generation during low flow periods.

5. How to prevent local "flash" floods that are caused by high-intensity summer rainstorms.

Floods have occurred periodically in the Columbia River drainage--more frequently in the Missouri. Average annual flood damage on the Columbia has been approximately 35 million dollars (11). On the Missouri it has averaged nearly 148 million dollars (14). A variety of climatic conditions can cause major floods in both drainages. Most common, however, is rapid snowmelt often accompanied by heavy rain. In the plains region of the Missouri Basin, snowmelt and/or rainfall on frozen soil have also caused floods.

Annually the Columbia River carries a sediment load estimated at about 19 million tons. This is considerably less than the 200 million tons estimated for the Missouri, but still enough to create substantial damage to downstream water-handling structures. About three-fourths of the sediment movement into these streams occurs during snowmelt runoff periods.

Some sections of both basins have suffered recurring crop failures aggregating millions of dollars of loss because of inadequate water supplies for late summer irrigation. This situation has been most prevalent in the Missouri Basin. Low winter flows have occasionally caused curtailment of power production resulting in "brown-outs" at various highly industrialized locations in the Pacific Northwest.

Major floods and water shortages occur because of untimely streamflow distribution. Sometimes there is too much; at other times, too little. Both of these problems have been alleviated somewhat on the Columbia and Missouri Rivers by construction of storage dams to regulate downstream flow. Projects proposed for both rivers should aid materially in solving the problems of flood control and water shortages.

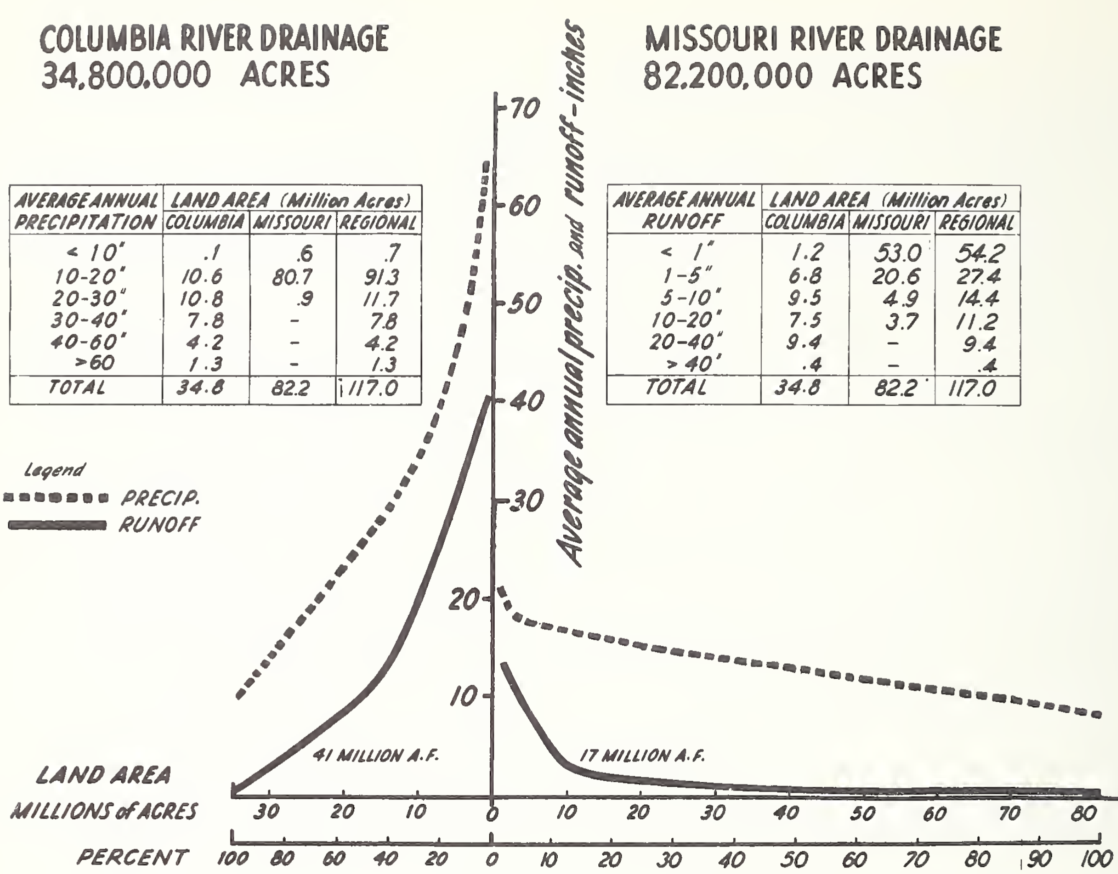
Despite this, two problems remain that storage and streamflow regulation by big dams will not solve. One of these is continuing sedimentation, with its attendant depletion of storage capacity and its high maintenance costs. The other is inability of large dams to prevent flood discharges and water shortages upstream, where sizable investments exist in both rural and urban developments. Methods of managing forest and range lands to regulate effectively streamflow quality, quantity, and timing must be found if the useful life of expensive downstream structures is to be protected and if important upstream areas are to be spared from floods and water shortages.

WATERSHED CHARACTERISTICS OF THE NORTHERN REGION

Hydrologically the upper Columbia and Missouri River drainages differ greatly (fig. 1).

PRECIPITATION

About 70 percent of the upper Columbia River drainage receives more than 20 inches of precipitation annually (15); 40 percent receives more than 30 inches, and 4 percent more than 60 inches. On the Columbia side of the Continental Divide two types of precipitation climate are marked by the



AVERAGE ANNUAL PRECIPITATION	LAND AREA (Million Acres) COLUMBIA	MISSOURI	REGIONAL
< 10"	.1	.6	.7
10-20"	10.6	80.7	91.3
20-30"	10.8	.9	11.7
30-40"	7.8	-	7.8
40-60"	4.2	-	4.2
>60	1.3	-	1.3
TOTAL	34.8	82.2	117.0

AVERAGE ANNUAL RUNOFF	LAND AREA (Million Acres) COLUMBIA	MISSOURI	REGIONAL
< 1"	1.2	53.0	54.2
1-5"	6.8	20.6	27.4
5-10"	9.5	4.9	14.4
10-20"	7.5	3.7	11.2
20-40"	9.4	-	9.4
> 40"	.4	-	.4
TOTAL	34.8	82.2	117.0

Figure 1.--Distribution of average annual precipitation and runoff in the upper Columbia and Missouri River drainages.

Bitterroot-Coeur d'Alene-Selkirk Mountain crest along the Montana-Idaho border. Westerly winds drop much of their moisture in crossing this barrier, and greater precipitation falls at comparable elevations on the west side than on the east. Heaviest rainfall comes during April, May, and June, the months when snowmelt runoff is greatest. Summer rainstorms of moderately high intensity occur, but not as frequently as on the Missouri side of the Continental Divide.

About 70 percent of the land area in the upper Missouri River drainage receives less than 15 inches of precipitation annually. Only about 1 percent receives more than 20 inches (15). The most significant climatic feature of the upper Missouri Basin is the great variation in precipitation from year to year, especially on the plains of eastern Montana. Here, precipitation varies annually from less than 30 to more than 200 percent of normal. Well over one-half of the annual precipitation of 10 to 15 inches in this section comes as rain during early summer. Late summer precipitation is sporadic and comes chiefly as high-intensity thunderstorms. Much of this precipitation is lost by rapid overland runoff that carries large amounts of sediment. In the higher mountains and valleys of the western part of the basin, most of the annual precipitation is snow (15).

RUNOFF

Average annual runoff from nearly 35 million acres in the Columbia Basin is about 14 inches, and represents about 41 million acre feet of streamflow (5). Of this amount, about 27 million acre feet, or 66 percent, originate on 17.8 million acres of national forest land. Main streams and tributaries in this basin have steep gradients, and tributaries are numerous, generally short, and drain rather small individual areas.

In the Missouri Basin slightly more than 82 million acres yield an average of about 2.5 inches of runoff that amounts to about 17 million acre feet of streamflow (5). Of this, about 6.2 million acre feet, or 36 percent, originate on 10.1 million acres of national forests. The flow of the Missouri River differs markedly from that of the Columbia except in the small headwater tributaries which have steep gradients. Many tributaries are large and long and their flow, like that of the main Missouri, is slow and sluggish.

Depending upon the manner in which they produce runoff, watershed lands in the Northern Region are of three kinds (fig. 2):

1. Arid lands, which ordinarily contribute less than 1 inch of runoff annually mostly as overland flow. These lands occupy about 54 million acres, or 46 percent of the region. Ninety-eight percent of these lands are in the Missouri Basin and are chiefly grass and shrub range.

2. Subhumid or semiarid lands, which produce more than 1 inch but usually less than 10 inches of runoff annually. These lands contribute most of their runoff as seepage flow from snowmelt during a short period in spring and early summer and contribute chiefly overland flow during the remainder of the year. They occupy about 42 million acres or 36 percent of the region. About 60 percent of these lands are foothills and lower mountain elevations in the upper Missouri Basin and are covered by a mixture of grass-shrub range and ponderosa pine—Douglas-fir forest. The remaining 40 percent occupies substantial areas along the western fringe of the region and in the valleys and lower mountain elevations of the Clark Fork and Flathead River tributaries of the Columbia in western Montana. Here, as in the Missouri Basin, grass and shrub cover, together with ponderosa pine and Douglas-fir forest, comprise the principal vegetation.

3. Humid lands, which yield more than 10 inches of runoff annually, nearly all as yearlong seepage flow. These lands, aggregating some 21 million acres, or 18 percent of the region, are the major water-yielding areas. Eighty-two percent of these lands are in the Columbia Basin, and are covered mainly by white pine, larch, spruce-fir, and lodgepole pine forests. The remaining 18 percent of the humid lands in the Missouri Basin, occupies the higher mountain elevations in central Montana where the main plant cover is lodgepole pine forests and subalpine grass-forb ranges.

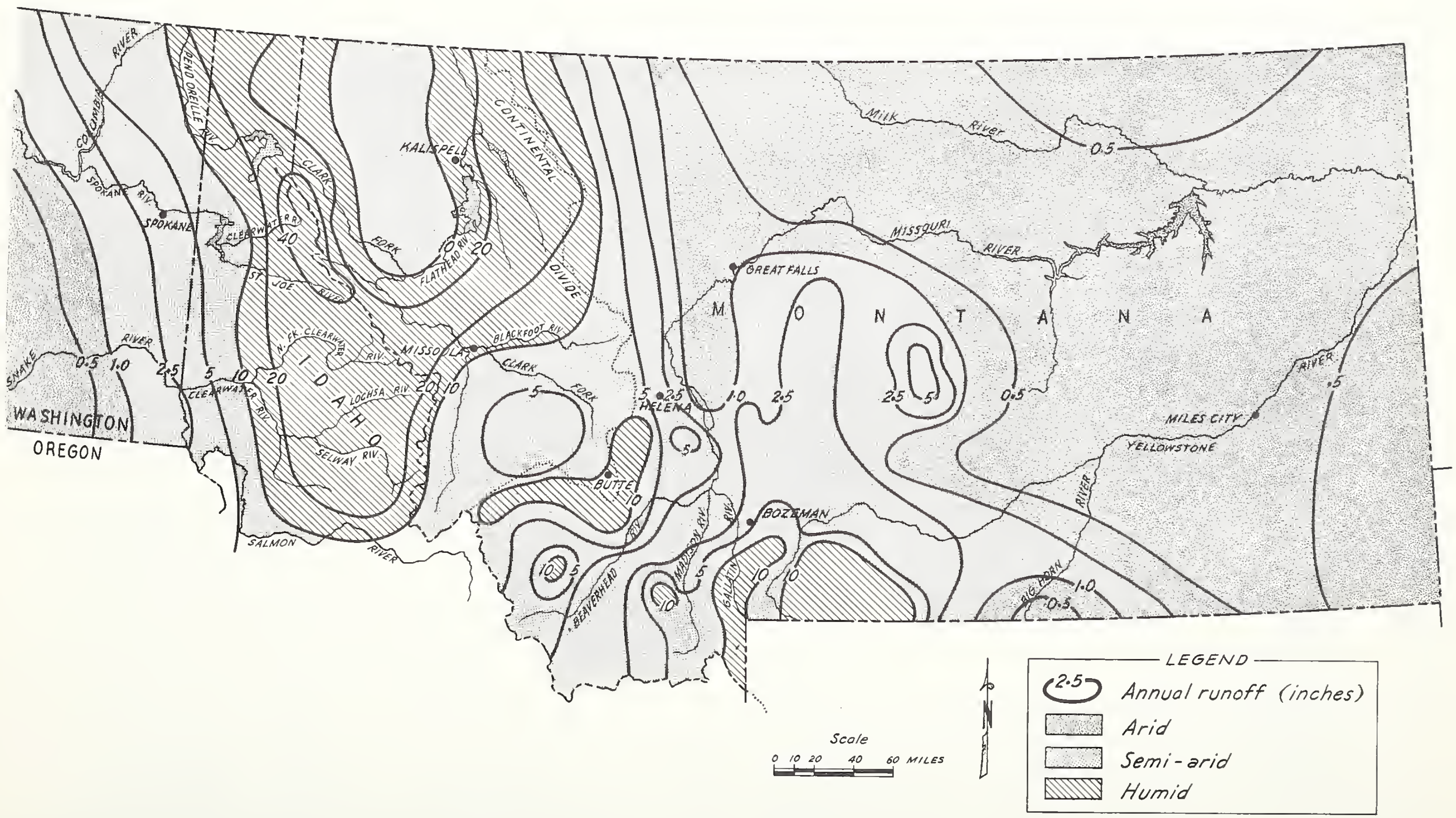


Figure 2.--Average annual runoff in the Northern Region.

When sufficient plant cover exists on these lands, only a small part of the annual precipitation becomes overland flow. Most of it contributes to seepage flow or is stored in the soil mantle and thus reduces soil moisture deficits created by evapotranspiration. When the protective plant cover is damaged and the soil is bared, each of these kinds of watershed lands can unleash undesirable and even destructive overland flow.

SOIL

Many kinds of soil are found in the Northern Region. Little is known about the location and extent of individual soils on the mountainous forest and range lands, and even less is known about their physical characteristics. In the summer of 1956, a cooperative soil survey was commenced by the Forest Service, Soil Conservation Service, and Washington State College on some national forests of this region. This survey should provide valuable information about the occurrence of different soils and important data about their physical characteristics. Hydrologists need more quantitative information about such soil characteristics as infiltration, storage, detachability, and transportability of soil particles, and how these characteristics are altered by different uses of the separate resources. Some important hydrologic features of the soil groups in this region can be related to their geologic origin and their behavior under use.

1. <u>Soils derived from granite</u>, because of their single-grain structure, are noncohesive and gully easily once they are cut by running water. These soils occur chiefly between the Salmon and St. Joe Rivers in northern Idaho on the Bitterroot Mountains, and in smaller areas scattered throughout western Montana.

2. <u>Soils derived from glacial silt deposits</u>, like the granitic soils, are single-grained, but they have finer texture and greater water-holding capacities. They are highly erodible when cut by running water and slip easily when saturated. These soils, deposited by glacial outwash, are scattered across the entire northern part of the region.

3. <u>Loessial soils</u> (windblown deposits from the Palouse prairie of eastern Washington) are fine-textured, productive soils and overlie residual soils at greatly varying depths. They have a high moisture storage capacity but are also highly erodible when cut by running water. These soils predominate along the western edge of the region.

4. <u>Soils derived from basalt</u> are fine-textured and more resistant to erosion than the other soils so far mentioned; they occur predominantly along the western edge of the region (as a result of the Columbia lava flows) and in and around Yellowstone Park.

5. <u>Soils of andesitic and rhyolitic origin</u>, associated with granitic soils, appear to be less permeable but also more stable when exposed to surface runoff. These soils are found chiefly in the mountains of western Montana along the Continental Divide.

6. Soils derived from hard sediments such as shales and sandstones, are silty, sandy, or gravelly loams. In the plains section and along the eastern side of the Lewis and Clark Mountains in Montana these soils are highly erodible and have been cut deeply by many streams. In parts of the upper Columbia Basin, soils from different hard sediments are quite stable, even under intensive forest operations.

7. Soft sediment and terrace soils, found mainly on benchlands and foothills of the upper Missouri Basin, are weakly consolidated alluvium. Two conditions make them heavy contributors of surface runoff and sediment: the sparseness of vegetation that often covers them, and the presence of clay layers that restrict percolation.

8. Soils derived from dolomite are fine-textured and have a tight subsoil. They have perhaps the most critical erosion potential in the region because they erode seriously even when the plant cover is only moderately disturbed. These soils cover extensive areas at intermediate and higher elevations throughout the Missouri Basin.

VEGETATION

Forests

A main concern in watershed management is the effect of forest cover and its treatment on streamflow and soil stability; hence, the extent and condition of forests in the Northern Region must be considered.

About 37 million acres of land in this region are classed as forests (18). Distribution of major forest types is shown in figure 3. Commercial forests in all ownerships total 27.2 million acres and is divided among the major forest types and geographic sections of the region as shown in table 1. Ninety-five percent of the forested area is in coniferous timber.

Table 1.--Area of commercial forest land by forest type and geographic location in the region[1/]

Forest type	Commercial forest area (millions of acres)			
	Northeastern Washington and northern Idaho	Western Montana	Eastern Montana	Totals
Lodgepole pine	1.5	2.3	2.4	6.2
Ponderosa pine	2.5	2.3	1.2	6.0
Douglas-fir	2.1	1.2	1.6	4.9
Larch	1.4	2.6	0	4.0
White pine	2.0	.4	0	2.4
Cedar-hemlock-fir	1.3	.1	0	1.4
Spruce	.2	.4	.3	.9
Woodland	.2	.1	1.1	1.4
Regional total	11.2	9.4	6.6	27.2

1/ Adapted from summary of forest survey statistics prepared for Region 1 as Task VI--Timber Resource Review.

Figure 3.--Distribution of major forest types in the Northern Region.

The most extensive areas of forest land are on the west side of the Continental Divide in northeastern Washington, northern Idaho, and western Montana. Here, on abundant water-yielding areas, the most important forest types are white pine, larch, spruce, lodgepole pine, and cedar-hemlock-fir. On less humid sites Douglas-fir and ponderosa pine predominate.

On the east side of the Continental Divide the important water-yielding forest areas are mainly lodgepole pine with spruce-fir as a stringer type along streams and in higher elevation basins. At intermediate elevations a somewhat drier belt supports Douglas-fir forests; these are bounded at their lower extremities by range land or open ponderosa pine forests.

Some indication of the hydrologic condition of forests in the region is given by the percentages of forest area by stand-size classes shown in table 2. In each of the three major geographic divisions of the region, sawtimber

Table 2.--Percent of commercial forest area in different stand-size classes[1/]

Geographic section	Stand-size classes			
	Sawtimber	Poles	Seedlings saplings	Nonstocked
Northeastern Washington Northern Idaho	42	27	17	14
Western Montana	42	33	21	4
Eastern Montana	29	49	8	14

1/ Adapted from summary of forest survey statistics prepared for Region 1 as Task VI--Timber Resource Review.

and pole stands together occupy from two-thirds to three-fourths of the forested land. Most of these stands probably exert near their maximum effectiveness for controlling overland flow and soil movement and for maintaining moisture storage in the soil mantle. This high proportion of larger sized trees in commercial forests makes early timber harvest desirable to prevent excessive losses from insects and disease. This means that, as intensified timber harvesting progresses towards sustained yield, areas of forest land occupied by newly regenerated sapling and seedling stands will steadily increase. These stands of small young trees, growing on land recently disturbed by road building, log skidding, and other activities connected with timber harvesting, probably do not control overland flow and soil movement nor provide as much soil water storage capacity as do older and larger sized stands growing on long-undisturbed sites. Continued forest use in this region will increase the probability of accelerated overland flow and the threat of floods and sedimentation.

Ranges

The Northern Region contains about 60 million acres of nonforested range land. Most extensive is the sagebrush-grass and low shrub-shortgrass range in the semiarid and arid parts of eastern Montana, occupying about 47 million acres. Some portions of this range extend into badland areas, and probably have always had normally high rates of sediment production; but a far larger portion contributes sediment to the Missouri River system at highly accelerated rates. During the 14-month period from September 1929 to November 1930, sediment measurements disclosed that the Big Horn River drainage discharged about 16.5 million tons of soil (17). This is an annual sedimentation rate of 667 tons per square mile, of which 76 percent occurred during high-intensity rainstorms in June, July, and August. In the same period the Yellowstone River discharged nearly 32.5 million tons of sediment.

Approximately 1.5 million acres of subalpine grass-forb range occupy the higher elevation watersheds of the Northern Region. About 70 percent of this range lies on the Missouri side of the Continental Divide. Extensive summer grazing has seriously depleted much of it. As a result, control over summer storm runoff and soil movement has been lost, and many small streams rising on this range carry large sediment loads during high runoff periods.

Open ponderosa pine-bunchgrass range is dispersed widely over the region on about 3 million acres of semiarid lands. This important source of livestock forage furnishes considerable winter feed for deer and elk. Some areas, especially along the western fringe of the region and in the upper Clark Fork and Kootenai drainages in western Montana, have been overgrazed. Much of the native bunchgrass cover has been replaced by a sparse cover of annual weeds; this change has increased overland flow and soil erosion.

Most of the remaining 8.5 million acres of range is interspersed with forest. Only the mountain meadows and parklike openings in the timber are useful for livestock. Because of sparse forage and difficult accessibility through dense forest stands this range is used mostly by big game.

About 6.3 million acres of national forest range in this region currently provide approximately 689,000 animal unit months of livestock grazing annually, distributed as shown in table 3. Most of the concern about range watershed conditions and the influence of grazing management practices on these conditions is centered in Montana, where about 81 percent of the regional national forest grazing occurs on approximately 75 percent of the usable range. By far the larger part of this use is on the Missouri side of the Continental Divide.

Table 3.--Animal unit months of actual livestock grazing and area grazed annually on national forest ranges in the Northern Region[1/]

State	Actual grazing		Area used	
	Animal months	Percent of total regional use	Millions of acres	Percent of regional area
Montana	560,000	81	4.7	75
Idaho	77,000	11	1.2	19
Washington	30,000	5	.3	4
South Dakota	22,000	3	.1	2
Total	689,000	100	6.3	100

1/ From Annual Grazing Report, Region 1, 1955.

A 1949 estimate (2) of range condition on national forests in the Northern Region indicated 56 percent of the range to be in satisfactory condition, 30 percent to be fair, and 14 percent to be poor. More recent estimates indicate that a substantially higher proportion is in poor condition. On numerous areas signs of range deterioration have not been recognized. Two outstanding needs are: (1) more precise evaluation of range condition and trend on areas not yet obviously depleted, and (2) restoration of deteriorated ranges to such condition that they can control storm runoff and soil movement.

SUMMARY

This brief review of watershed characteristics reveals pertinent facts and relationships regarding watershed conditions in the Northern Region.

1. Average annual precipitation of about 29 inches on Columbia Basin lands is almost double the 15 inches received by lands in the Missouri Basin.

2. Three-fourths or more of the annual precipitation in the Columbia Basin falls as snow. In the Missouri Basin, snow accounts for only about one-half of the annual precipitation.

3. About one-half of the Columbia Basin's average annual precipitation, or approximately 14 area inches of water, runs off as streamflow. In contrast, only about one-sixth of the Missouri Basin's annual precipitation, or approximately 2.5 inches, appears as streamflow. From two-thirds to four-fifths of the annual discharge of both basins occurs between March and July.

4. Evapotranspiration causes loss of only about one-half of the precipitation in the Columbia Basin, but about five-sixths of the precipitation in the Missouri Basin. The greater loss is in the area that receives less total precipitation but more of it as intermittent summer rainstorms.

5. Nearly all the soils are highly erodible when bared by disturbance. They are shallow and have low storage capacity on the steep slopes. This condition emphasizes the necessity of maintaining protective plant cover to control overland flow and to maintain moisture storage capacity.

6. A high proportion of the forest cover is mature or near-mature and probably exerts close to its potential for flood control and consumptive water use. This hydrologic condition likely will be altered by timber harvest, which will convert these forests from an old to young growth condition.

7. A large percentage of range land is in unsatisfactory condition for controlling storm runoff and soil erosion.

WATERSHED MANAGEMENT PROBLEMS

The numerous problems of watershed management encountered in the Northern Region can be classified into three general groups.

First, and probably most pressing is the problem of maintaining the normal hydrologic functioning of watersheds under use without creating conditions that lead to a rapid and severe state of deterioration. Second, but of less magnitude is the problem of restoring damaged watersheds. Both of these problems are concerned with development and application of effective measures for controlling overland flow and soil erosion. Third, limited in extent, but growing in importance, is the problem of improving water yields by increasing streamflow or by altering its time of delivery to meet seasonal demands for water more satisfactorily.

Two general kinds of information about watershed management are needed to provide solutions to these problems. One is quick development of protection criteria or guides for such activities as road building, logging, and grazing. The other is development of quantitative relationships that express the hydrologic effects of management treatments on streamflow and soil stability characteristics of forest and range watersheds.

PREVENTION OF FOREST WATERSHED DAMAGE

Prevention of damaging increases in streamflow peaks and sediment from forests of the upper Columbia Basin is the most important watershed management problem for several reasons. These forests, especially those of the white pine, larch, spruce-fir, and cedar-hemlock types, receive heavy snowfall each year and accumulate extremely deep snowpacks. Snowpacks melt most rapidly during April, May, and June--the months of heaviest seasonal rainfall. Consequently, soil mantles must dispose of larger amounts of water here than in any other part of the region. These forests--about 20 million acres--are frequently a source of damaging floods on the Columbia River or its tributaries.

For the past several years the annual cut of timber in the Northern Region has been nearly 1 billion feet from national forests and more than 800 million feet from state and private forests. Ninety-five percent of this timber has come from Columbia Basin watersheds. This harvest removed all or part of the forest from about 112,000 acres annually. It also required building approximately 1,600 miles of truck and jammer roads and 1,000 miles of tractor trails, construction that removed nearly all protective plant cover from about 10,000 acres each year. It is estimated that the volume of merchantable sawtimber in the region (about 136 billion board feet (16)) can support a sustained allowable timber cut of nearly 2.7 billion feet annually, an increase of about 50 percent above the current cutting level. The area cut and occupied by roads and skidtrails can be expected to increase correspondingly.

Wherever timber is removed from such large areas, and especially when it is removed in clear-cut blocks as is commonly done in this region, the interception and shading effects of the forest may become negligible for a period of 10 to 20 years until new stands become established (fig. 4). During this interim period the soil mantle inevitably receives as precipitation more water requiring disposal. Following timber removal, transpiration of water and moisture storage opportunity in the soil mantle are reduced. This condition can lead to substantially aggravated flood discharges from forest lands. The normal storage capacity of forest soil is also reduced by removing litter and humus normally incorporated in the upper soil layers; this may be caused by road building, log skidding, fire, or erosion. The resulting increase in overland flow accentuates the potential for larger flood peaks.

These combined circumstances raise important specific questions about how much timber can be removed safely from a watershed, and in what manner, without aggravating flood peaks and sediment production:

1. How can logging roads be located and constructed to prevent or reduce soil movement into stream channels?

2. How can overland flow from road and skidtrail surfaces be controlled to prevent its entry into stream channels?

3. Where and in what patterns can timber be cut so that the rising stage of snowmelt streamflow begins earlier and the receding stage continues longer into the summer without increasing the height of peak discharge?

4. How can slash and other logging debris be disposed of without increasing overland flow and soil erosion?

Figure 4.--A clear-cut block of white pine timber on the Deception Creek Experimental Forest in northern Idaho.

White pine forests constitute those areas for which solutions to these problems are most urgently needed. The 2.4 million acres they occupy have the heaviest annual runoff in the region; it averages from 20 to more than 40 inches. These forests are infected with blister rust, control of which requires the harvesting of timber in relatively large blocks. The possibility of developing rust-resistant strains of white pine gives some hope for eventual greater flexibility in methods of cutting. The necessity for cutting white pine forests in large blocks creates the hazard of increasing peak streamflow from any given watershed in these forests. The granitic, glacial silt, and loessial soils, highly erosive when disturbed, are the most critical problem areas in white pine forest because of their potential for producing sediment.

These problems are almost as important in the larch and spruce-fir forests of western Montana and extreme northern Idaho, where snowpacks and water yields approach those in the white pine belt.

PREVENTION OF RANGE WATERSHED DAMAGE

Nonforested ranges occupy nearly 52 percent of this region. Except for those at high elevations, these ranges individually yield only small amounts of streamflow. Because collectively they occupy large areas, their total streamflow amounting to about 12 million acre feet annually is more than one-fifth of the regional water production. The most critical hydrologic problem on these ranges is the manner in which this water is yielded as streamflow and the accompanying sediment production. Nearly half of the rangeland in the region is not controlling storm runoff and erosion effectively. As a result, water from these ranges reaches stream channels as overland runoff laden with eroded soil. From two-thirds to three-fourths of the total sediment load carried by streams in this region is produced on deteriorated rangelands.

Three important physical processes contribute to range deterioration and loss of control over water and soil. One of these is reduction in surface area covered by plants and litter that follows the downhill soil sloughing caused by animals trampling on slopes. Another is soil compaction produced by this trampling, especially on gentle slopes and on dense or very wet soils. A third is reduction in the litter produced by range vegetation following repeated removal of excessive amounts of herbage as forage. Adequate information about litter production potentials of plant cover and tolerable limits of forage utilization and disturbance from trampling is lacking. Consequently, it is difficult to design effective methods for preventing depletion of plant cover and soil and loss of control over water and soil on the remaining undamaged ranges in the region. Specific quantitative knowledge is needed about:

1. How much and what kind of plant cover and what soil conditions are required to effectively cope with high-intensity summer rainfall?

2. To what extent and by what methods can ranges be grazed without destroying the plant cover and soil conditions that provide control of storm runoff and soil stability?

Figure 5.--The good cover of vegetation and litter controls storm runoff and erosion on this subalpine grass-forb range.

Solutions for these problems are needed most urgently on subalpine grass-forb, sagebrush-grass, and low shrub-shortgrass ranges in the upper Missouri Basin in Montana (fig. 5). Here, high-intensity summer rainstorms occur frequently on dolomitic and soft and hard sediment soils that are very unstable when protective plant cover is lacking.

RESTORATION OF DAMAGED FOREST WATERSHEDS

Wildfire and faulty road-building practices have been the two chief causes of forest watershed damage in the Northern Region. In the 40-year period from 1908 to 1947 more than 12 million acres burned, some areas two or three times (1). New stands of timber have regenerated on some burned areas, but more than 2 million acres that received multiple burns are either unstocked or are very poorly stocked with young timber. A large part of this multiple-burned area is in northern Idaho and western Montana. Active erosion continues over much of it (fig. 6). Tree planting programs are under way or planned for restoring forest cover to about 500,000 acres of the best timber-growing sites. On the remainder, improved plant cover is still needed to stabilize the soil.

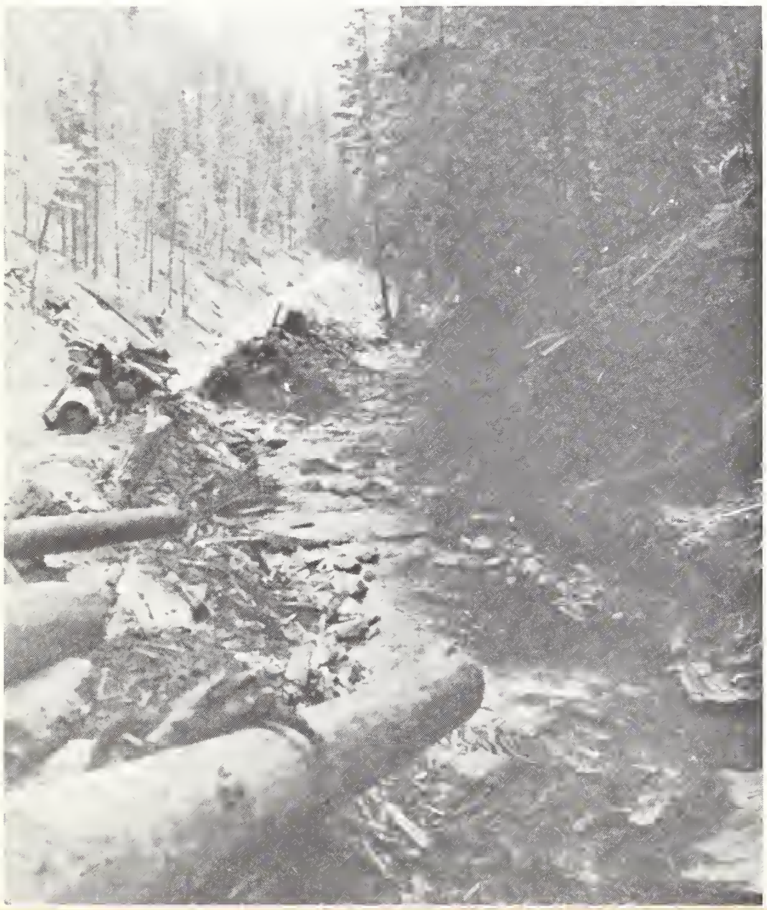
Active erosion continues on numerous steep, poorly located and improperly constructed roads in logging areas. Major trouble spots are deep road cuts, long fill slopes, and poorly drained road surfaces, especially where they crowd stream channels (fig. 7). Repeated reseeding on many areas has failed to establish plant cover. Plausible causes for failure are unstable seedbeds, insufficient moisture available to seedlings near the soil surface, and lack of fertility in the raw, exposed subsoils.

If flood peak discharges and sediment are to be held in check, methods to control overland runoff and soil erosion on these damaged forest watersheds must be developed. To do this, we must learn:

Figure 6.--Protective forest litter and humus on this slope have been almost completely destroyed by fire.

1. What vegetation and what mechanical measures can be used effectively to control overland flow and stabilize soil on eroding burns, bared road surfaces, cuts, and fills?

2. How and in what degree do these measures affect streamflow and sediment production?



These problems are more closely associated with soils than with forest types. The loessial and granitic soils in north central Idaho, the glacial silt soils across the northern part of the region, and the dolomitic soils in the upper Missouri Basin are the most vulnerable to erosion in the absence of protective plant cover. Major forest types usually found on these soils, and in which these problems are of prime concern, are white pine, larch, spruce-fir, and lodgepole pine.

Figure 7.--This road was built too close to the stream channel. It reduced channel capacity and created a direct source of sediment for the stream.

RESTORATION OF DAMAGED RANGE WATERSHEDS

The need for more precise definition of present condition and trend on range areas that are in neither very good nor very poor condition has been pointed out. Despite some deterioration from overuse, many ranges still support abundant cover of native perennial vegetation. Some overland flow and soil movement may occur during heavy rainstorms, but most of the topsoil is still intact. Most such ranges could return naturally to a satisfactory condition by careful management that would include protection from excessive grazing.

On the other hand, on more than 200,000 acres of native range on the national forests and on more than 2 million acres of range outside these forests the perennial plant and soil cover has become so depleted that runoff has removed several inches of topsoil and carved pronounced gully systems (fig. 8). Streams rising on or flowing through these ranges carry large sediment loads during summer storms and periods of snowmelt runoff. Stream banks and channels have been torn by these sediment-laden discharges, and thus have contributed additional sediment. The quality of irrigation water from these streams has progressively deteriorated. If damaging peak discharges and the eroded soil they carry are to be controlled, methods of restoring plant cover and soil conditions that permit torrential rainfall to enter the soil mantle where it falls rather than to run off over the ground surface must be found. Studies are needed to determine:

1. What grazing management methods, artificial revegetation measures, and mechanical structures are required to restore runoff control and soil stability to badly damaged ranges?

2. How do restoration measures affect streamflow peaks, water yields, and sediment production?

Figure 8.--Loss of control of storm runoff on this deteriorated subalpine range has caused extensive sheet erosion and gully formation.

Critically depleted areas that cause most concern lie on the low shrub-shortgrass range in eastern Montana, on the subalpine grass-forb range in the higher mountains of the upper Missouri Basin, and on the sagebrush-grass range in the foothills of these mountains. On the low shrub-shortgrass range, abandoned dry-farm lands on hard sediment and glacial silt soils appear to be major sources of sediment and most in need of rehabilitation. Unstable dolomitic soils are major problem areas on subalpine grass-forb range. On sagebrush-grass range, which lies mainly on soft sediment and terrace soils, excessive winter use by game animals on south-facing slopes and wind-blown ridges has made these locations the main problem areas.

IMPROVEMENT OF WATER YIELDS ON FOREST LANDS

Water shortages occur throughout the Missouri Basin about 1 year in 10. Shortages also occur locally within the basin almost every year. Streams that have steep profiles and major tributaries provide little opportunity for surface storage of water. About 75 percent of the annual streamflow is discharged by early July; hence, upper basin irrigation depends upon variable and often inadequate streamflow in summer and fall. Increased water supplies and, even more important, improvement of streamflow timing are needed to meet irrigation demands.

The best opportunity for creating hydrologic conditions needed to improve summer water yields lies in the forested watersheds at high elevations in the upper Missouri Basin, where most of the precipitation is snow. Another opportunity exists in heavily vegetated streamside areas where much water is lost by transpiration. Cutting of forests and removal of riparian vegetation increase water yields, but the magnitude of increase in relation to the treatments required, the extent to which timing of streamflow can be altered, and the effects of treatment on peak discharges and sediment production are far from being known. It is important to know whether streamflow peaks increase in damaging amounts and whether streamflow can be delayed in terms of weeks or only days. Research is needed to determine:

1. Where and in what patterns timber can be cut so that any additional streamflow from snowmelt will be distributed more uniformly over the receding stage during the summer without increasing the height of peak streamflow?

2. How much timber can be removed safely from watersheds without creating flood and sediment hazards?

3. How, and to what extent, removal of riparian or other streamside vegetation affects water yields and peak streamflow?

Figure 9.--Clear-cut blocks in a lodgepole pine forest in Montana.

Solutions for these problems are urgently needed for those lands that support the lodgepole pine type. This forest type occupies about 2.5 million acres of the greatest water-yielding land east of the Continental Divide in Montana (fig. 9). Until recently, relatively little lodgepole pine timber was cut. Increased demands for lumber and improved techniques in wood utilization have combined to accelerate timber harvesting from these forests during the past few years. Silvicultural conditions favor clear cutting of lodgepole pine in large blocks. These forests are infected with dwarfmistletoe, a parasitic forest disease that develops most intensively within a distance of about one tree height from clear-cut borders. Large clear-cut blocks tend to reduce the perimeter exposed to infection, but they also tend to increase the hazards of higher runoff peaks and erosion. Dolomitic soils are the most critical areas in lodgepole pine forests because they are most extensive and can produce large quantities of sediment when disturbed. They also generally have deep soil mantles that afford more opportunity for increasing water yields by cutting timber.

IMPROVEMENT OF WATER YIELDS ON RANGE LANDS

Need for improved water yields in the Missouri Basin directs consideration to range lands as a possible source of additional water or as an area where timing of streamflow can be altered. Studies in Utah (7) and Colorado (19), as well as in the Siberian steppes (4), indicate that drifting snow can be piled into deep packs where melting may be delayed sufficiently to lower the peak streamflow and to prolong summer flow. The chief opportunity for snow management to accomplish these objectives exists on about 1 million acres of subalpine grass-forb range (fig. 10). In the Northern Region this range has received no attention as a possible source for water yield improvement. More knowledge is required about the following:

Figure 10.--Late summer remnants of snowbanks on a subalpine range in Montana.

1. How, and to what extent, such structures as drift fences and planted windrows can be employed to accumulate snow into deep packs and retard melting?

2. To what extent do such treatments affect the amount of streamflow and the time of its occurrence?

Considerable evidence indicates that increased yields of water may be obtained from some range lands by converting deep-rooted plant cover that consumes much water to a shallow-rooted cover that transpires less (3, 6, 9). Presumably, under these circumstances, less water would be required to recharge the soil mantle to capacity; hence, more water would be available for streamflow. Prerequisite to increased water yields obtained in this manner is the need to maintain high quality of water by keeping a protective plant cover on the ground to control overland runoff and prevent erosion. Studies are needed to learn:

1. How to convert a deep-rooted plant cover to a shallow-rooted one and maintain it?

2. How, and to what extent, such conversion affects the amount and rate of streamflow and sediment production?

Lying below and intermingled with the Douglas-fir forests of the upper Missouri Basin in Montana are about 2 million acres of sagebrush-grass range. Except for limited use by antelope and deer for winter forage, the sagebrush of this range is practically worthless. If most of this range could be converted to grassland, its value for cattle forage would be increased and, at the same time, water yields might be increased, especially on deep, soft sediment and terrace soils having high water storage capacities.

SUMMARY

Watershed management problems and the areas in this region where they need most attention are summarized in table 4. Three of these problems deserve immediate research.

Table 4.--Major watershed management problems and problem areas in the Northern Region

Problems	Areas			Research priority
	Drainage	Vegetation	Soil	
How to manage forests and ranges to prevent damaging increases in snowmelt runoff peaks and sediment	Columbia	White pine forest	Loessial-granitic-glacial silt	1
	Columbia	Larch-spruce-fir forest	Glacial silt	2
	Missouri	Subalpine range	Dolomitic	3
How to manage forests and ranges to improve summer water yields without increasing streamflow peaks and sediment production	Missouri	Lodgepole pine forest	Dolomitic	1
	Missouri	Subalpine range	Dolomitic	2
	Missouri	Spruce-fir forest	Dolomitic	3
How to manage damaged ranges to restore control of summer storm runoff and sediment	Missouri	Subalpine range	Dolomitic	1
	Missouri	Sagebrush-grass range	Soft sediment	2
	Missouri	Low shrub-shortgrass range	Hard sediment	3

First is the problem of managing white pine forests in the deep snowpack belt of northern Idaho and extreme western Montana to avoid aggravating snowmelt runoff peaks and sediment production. This problem should have highest priority because of the potential flood and sedimentation hazards contingent upon clear cutting timber from areas that normally produce near-flood peaks of snowmelt runoff.

The second major problem is the management of lodgepole pine forests in the snowpack zone of the upper Missouri Basin to increase the amount and improve the timing of summer streamflow without incurring damaging increases in peak runoff and sediment production. Solution of this problem is urgent for two reasons. One is the hazard of increasing flood and sediment production following clear cutting of timber from these areas that receive deep winter snowpacks and frequent torrential summer rainstorms. The other is the rapid expansion of timber harvesting, which may ease the increasing shortage of water in the upper Missouri Basin by improving summer water yields.

A third problem is restoration of plant cover and soil conditions capable of controlling summer storm runoff and erosion on damaged subalpine grass-forb ranges on the higher mountains of Montana. Solution of this problem should have high priority because large volumes of sediment now flow into downstream structures from these ranges.

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